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Week 13: Photosynthesis
Class: BIOL 101: General Biology I

LEARNING OBJECTIVE

To understand how plants convert solar energy in to chemical energy (sugar) in photosynthesis and store those sugars for use by themselves and other organisms to be used in cellular respiration

INTRODUCTION

While it is important for you to be able to explain the overall process of photosynthesis and list the reactants and products of photosynthesis – it is perhaps even more important for you to understand how a changing environment can and will impact plants and their ability to photosynthesize. In part, you will need to be able to explain the role of light wavelength in photosynthesis and how photosynthetic pigments alter the rates of photosynthesis in different plants. This will help you understand how changing atmospheric conditions will impact photosynthesis rates in plants. You will also need to think about how pollutants can impact plants and their ability to photosynthesize – and ultimately how that impacts their ability to produce sugars for you and all of the other consumers on this planet!

ACTIVITY, DATA COLLECTION & ANALYSIS

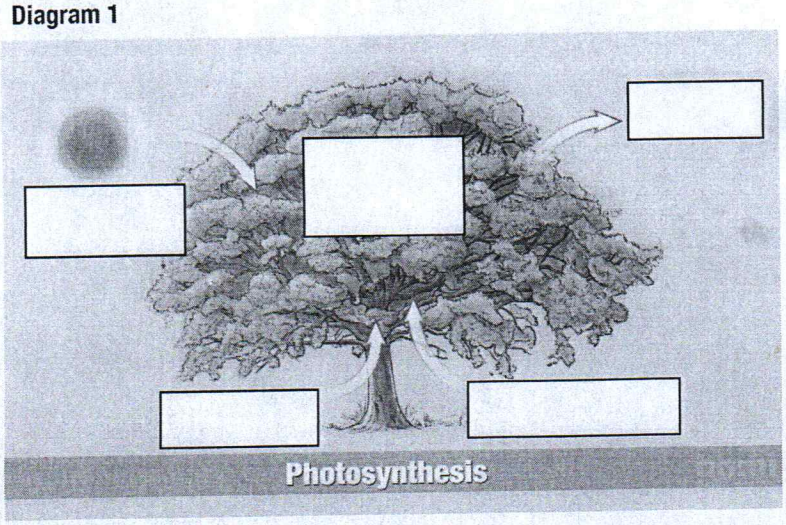
1. What is the balanced equation for photosynthesis (production of glucose)?

2. What stage of photosynthesis produces the greatest amount of sugar for the plant?

3. Why do plants need mitochondria if they have chloroplasts?

4. Your instructor will show you an animation in class. On Diagram 1 below, fill in the labels with photosynthesis's main inputs and outputs of matter and energy.

Diagram 1



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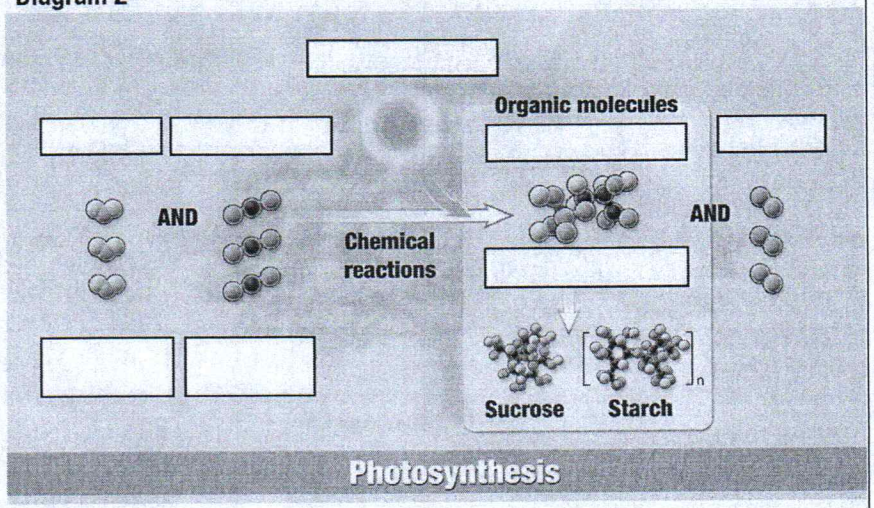
5. On Diagram 2, fill in the labels with the following descriptions. Some of the objects have multiple labels.
Word bank: water (H_2O), carbon dioxide (CO_2), oxygen (O_2), G3P (sugar), electron acceptor, electron donor, carbohydrates, energy input

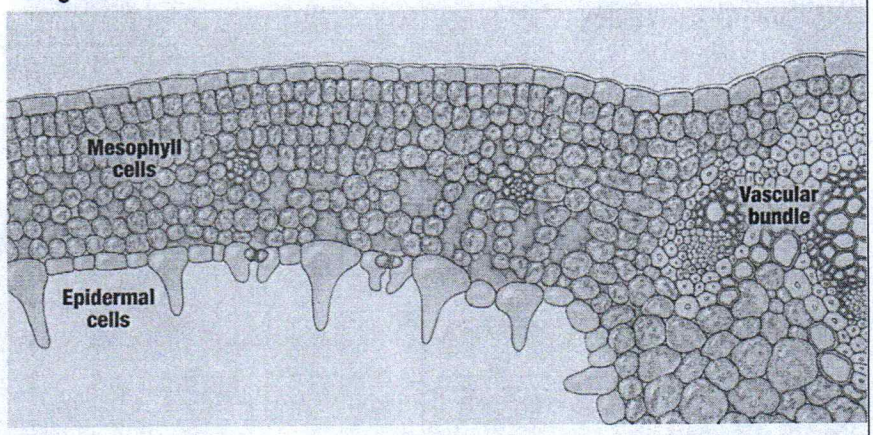
Diagram 2



6. On Diagram 3, complete the following tasks.

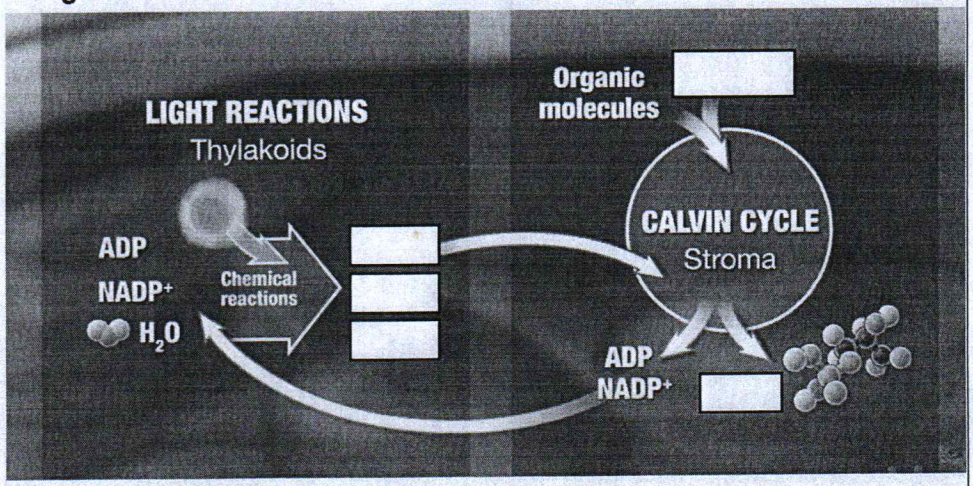
a. Draw how CO_2 gets into the leaf.
b. Draw how O_2 gets out of the leaf.
c. Label the name of the structure through which these gases pass.

Diagram 3



7. On Diagram 5, fill in the labels with the following descriptions to show the connections between the light reactions and the Calvin cycle. Word bank: carbon dioxide (CO_2), oxygen (O_2), G3P (sugar), ATP, NADPH

Diagram 5



8. Describe how oxygen gas (O_2) is produced during photosynthesis. Include the specific structures in the plant where the reaction occurs.

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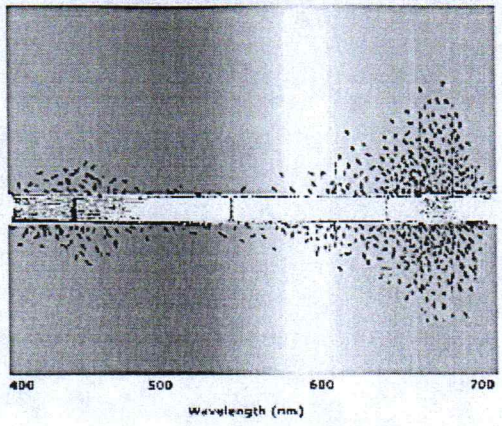
9. Describe how ATP is produced in the light reactions.

10. Bacteria living in water tend to cluster in areas with high concentrations of oxygen. As many non-photosynthesizing bacteria rely on oxygen for cellular respiration (for production of cellular energy, ATP), where would the oxygen in the water be coming from? This is a biological action spectrum from Theodor Engelmann's experiments with bacteria in the 1880's. The black "specs" within the colored bands are bacteria, and the white "bar" across the middle contains algae.

How can you use this spectrum to explain where oxygen comes from in the water? (*Note: a color copy of this image will be on myCourses for your reference.*)



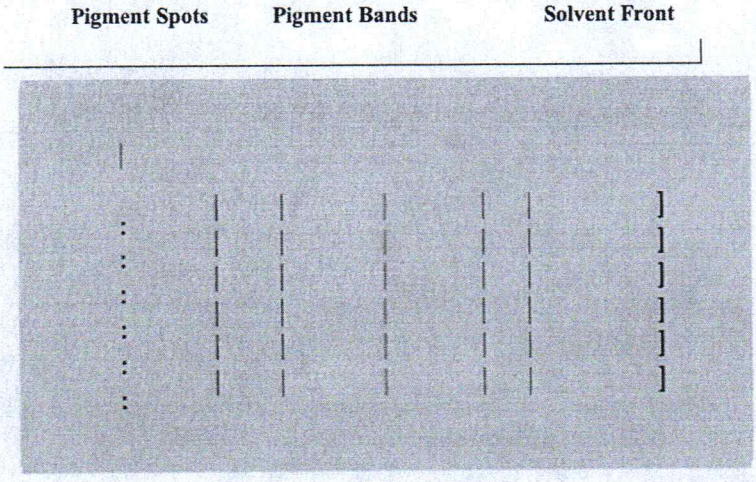
Purple Blue Green Yellow Orange Red

Analyzing Photosynthetic Pigments:

There are several different chromatographic techniques to study pigments. The one selected for this activity is thin layer chromatography (TLC). A thin layer of Silica Gel is placed on an acetate sheet and a pigment extract of the plant to be studied is spotted on the silica gel. The pigment molecules become absorbed to the silica gel. One end of the slide is placed in a developer solvent that begins to move up the silica gel by capillary action. As the solvent passes through the spot of absorbed pigment molecules, they dissolve in the solvent and are carried upward by the solvent. Because some kinds of pigment molecules dissolve more quickly in the solvent than others, some pigment molecules will move quickly up the slide and others more slowly - some pigments will be seen near the top of the slide and some near the bottom.

The various pigments separated by this procedure can be identified by their position on the TLC. Under a given set of conditions, each pigment will always travel at the same rate, called the **rate of flow**, or Rf. The Rf is a ratio of the distance traveled by the pigment to the distance traveled by the solvent. Thus:

$$Rf = \frac{\text{Distance traveled by the pigment}}{\text{Distance traveled by the solvent}}$$



Because each pigment will travel at a different rate, a function of its chemistry, each pigment can be identified and distinguished from other pigments by its Rf. Most importantly, different pigments with the same apparent color can be distinguished by their Rf values. In this activity, you will analyze the results of thin layer chromatography to identify the various pigments found in the extract of leaves collected from around RIT.

Direction of solvent movement is from left to right in this diagram.

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The solvent used in this procedure typically separates 7-8 pigments from leaf chloroplasts with the following Rf values:

Pigment Group	Pigment Name	Color	Rf Value	Solubility
Xanthophylls	Neoxanthin	Yellow	0.09	Least Soluble
Xanthophylls	Violaxanthin	Yellow	0.21	
Xanthophylls	Lutein	Yellow	0.40	
Chlorophylls	Chlorophyll b	Yellow-green	0.46	
Chlorophylls	Chlorophyll a	Green-blue	0.60	
Chlorophylls	Pheophytin	Gray	0.72	
Carotenes	Beta-carotene	Yellow-orange	0.98	Most Soluble

Activity:

Observe the bands of pigment on the silica gel pictures given at your table. Using the ruler, measure the distance from the origin to the center of each pigment band. If the band is bowed (faster migration in the center of the strip), measure the leading edge.

Calculate the Rf for each pigment band by dividing the distance the pigment traveled by the distance the solvent traveled. Record these values in the Data Table Below.

Compare the results of your chromatograms against the Pigment Group table above. You may not see all of the bands listed; or, you may see a few extra bands of unidentified pigments. Use the table and your calculated Rf values to identify the pigment bands on your gels. Record the identified pigments in the Data Table Below.

Pigment Number	Rf Value	Observed Color	Pigment Name
1			
2			
3			
4			
5			
6			
7			

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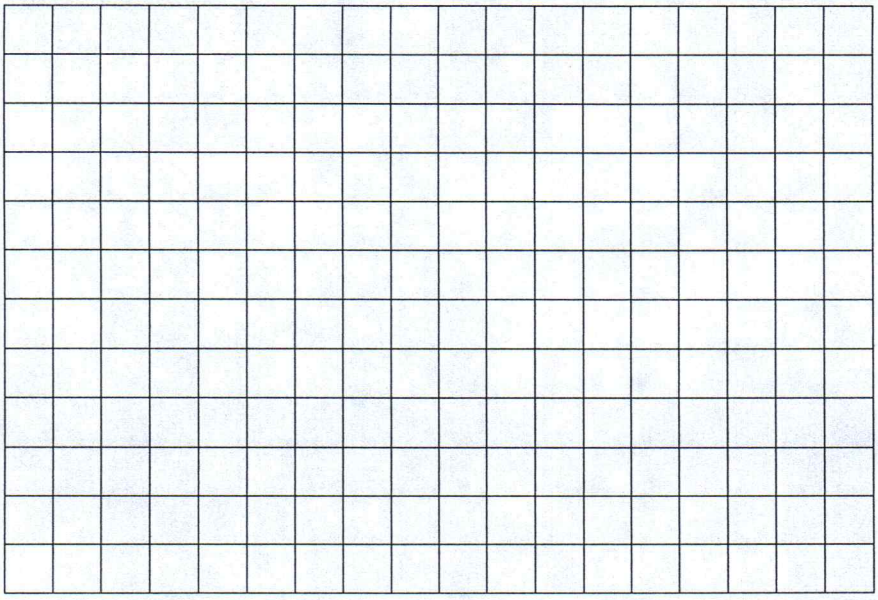
Are all pigments created equal?

Some wavelengths, regardless of intensity, do not promote photosynthesis. Why is this so? To answer this question, we need to examine the ability of the pigments of the chloroplast to absorb light to which it is exposed. After all, light is useless in photosynthesis unless the pigments of the chloroplast can absorb it!

A spectrophotometer can be used to show those wavelengths of light that are absorbed by the pigments (e.g., Chlorophyll a and Chlorophyll b as you have seen in class), and those that are reflected. The same pigments that you observed by thin layer chromatography above were analyzed by scanning spectrophotometry and the absorption spectrum of the pigments are provided at your table. The pigment absorption was measured from 350 nm to 800nm. Graph these results with wavelength on the x-axis and absorption on the y-axis. Make sure to differentiate the various pigments in some way on your graph (e.g., colored lines, dotted lines, etc.)



Based on your graph, answer the following questions.

1. What does the peak absorption wavelength on a pigment absorption spectrum represent?

2. Why do different pigments exhibit variability in their absorption spectra? How does this variability contribute to the diversity of colors observed in nature?

3. In the context of photosynthesis, how does the absorption spectrum of chlorophyll relate to the efficiency of light absorption for photosynthetic processes? What implications does this have for plant productivity?

4. If you compare the absorption spectra of chlorophyll and carotenoids (some of the pigments you saw in your TLC analysis), what differences would you expect to find, and how do these differences contribute to their respective roles in photosynthesis?

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